Flugg for ν-Beam Simulation

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Introduction

- Zarko has already given a good introduction to g4numi and how Flugg relates to it.
  - g4numi is a Geant4 simulation of the NuMI beamline
  - However, the physics of Fluka is preferred to Geant
  - Flugg provides an interface between Fluka and Geant4 so that a Fluka simulation can run over the g4numi geometry
- The target, as simulated by Flugg, was ~identical to that as simulated with just Fluka.
- The physics case for Flugg: **downstream interactions**
  - If the only hadronic interactions of interest happen in the target, then you could just take the original gnumi approach (separate target and beamline simulations)
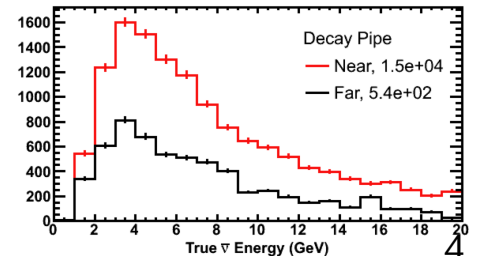
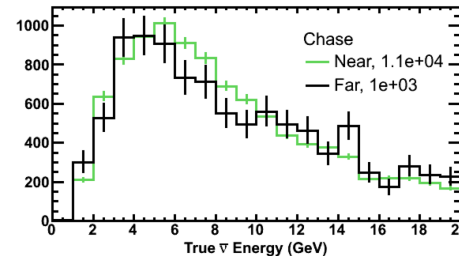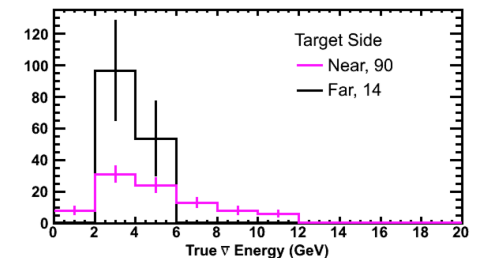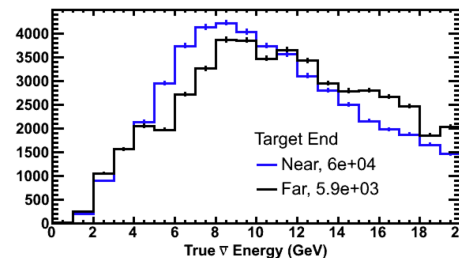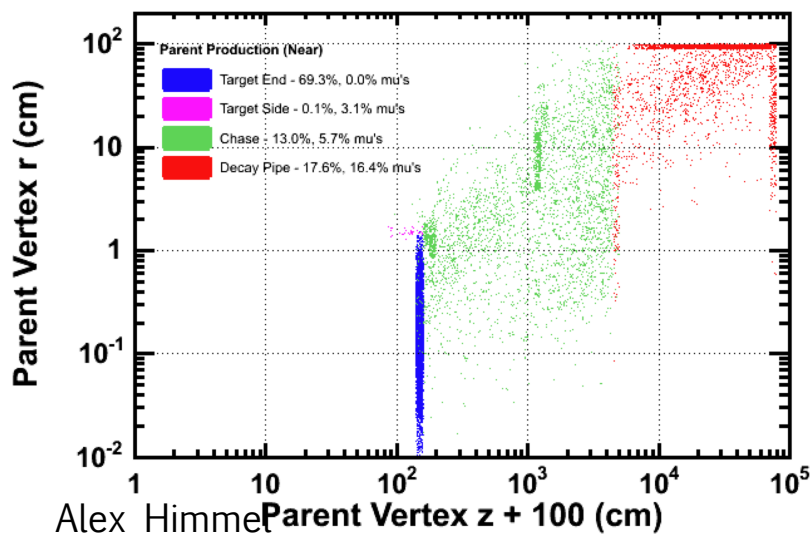Alex Himmel

Downstream Interactions

- The MINOS interest in downstream interactions is two-fold:

- Downstream interactions are a significant source of wrong-sign neutrinos (antineutrinos in the neutrino beam)

  - About 30% of the Near Detector events are from parents produced outside the target

  - A little more than half of those come from the decay pipe

- The decay pipe needed to be filled with helium to avert a structural failure

  - Suddenly there were significantly more hadronic interactions happening in the decay pipe
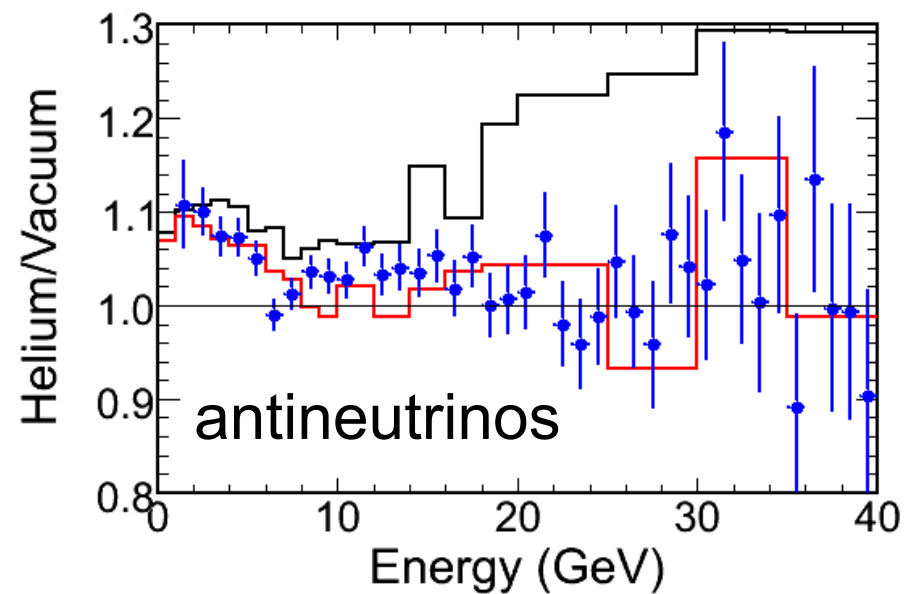
Downstream Interactions

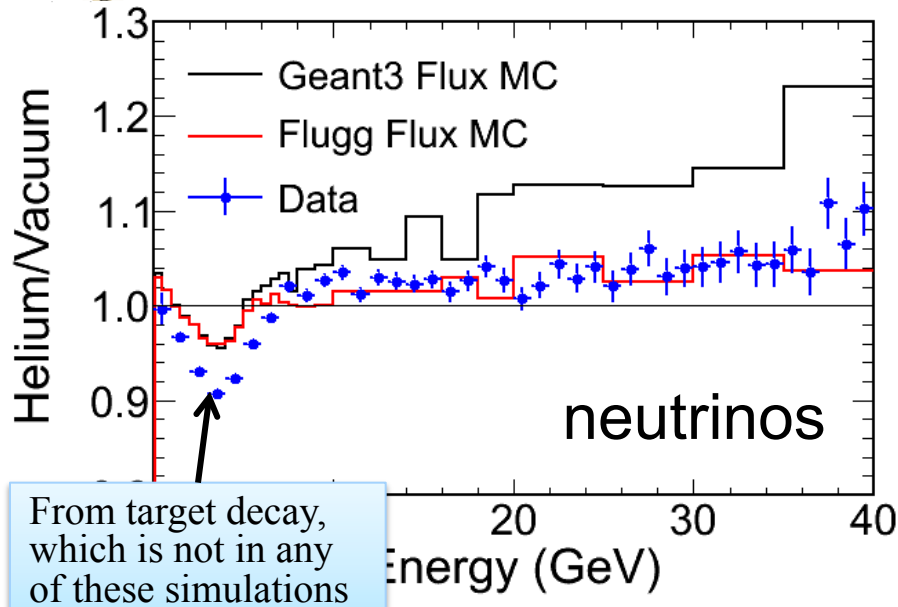- Why we care about downstream interactions: extrapolation
  - An example from MINOS's first antineutrino analysis:
  - Neutrinos from decay pipe parents make up 17% of the ND but only 7% of the FD

- This means uncertainties in their flux only partially cancel between the two detectors.

- This happens because the decay pipe is ~700 m long, but the ND is only ~1 km from the target.

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Flugg vs. Geant

neutrinos

From target decay, which is not in any of these simulations

antineutrinos

- Above I compare the ND spectrum before and after adding helium.

- The gnumi MC (black) shows a large rise at high energy that does not appear in data (blue).

    - I've been told that there is a "known problem" with GFluka predicting too many high x_f-particles

- Flugg, on the other hand, does an excellent job of modeling the change from adding helium to the decay pipe.

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5

Practical Notes

- ## Software Requirements:
  - Geant4, Fluka, Flugg
    - Flugg can be very picky, so I would recommend getting the latest Flugg, which should work with the latest Fluka, and getting the version of Geant4 it was written for.
  - From the numisoft repository: g4numi, g4numi_flugg

- ## The experience of developing and running with Flugg
  - Running the Flugg executable and handling its output can be a little involved
    - With some clever scripting the process can be made relatively painless
  - While Fluka and Geant4 are both popular with large developer communities, Flugg is a niche package
    - That being said, Flugg is not abandoned (the latest version was released last year)
    - However, if you run into a bug you might need to go digging around in the Flugg source yourself
    - When I was working with it, I submitted several bug fixes related to handling non-uniform magnetic fields (the program would seg fault without them).

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Conclusions

- Flugg gives good results when downstream interactions are important.
  - It certainly gives better results than the Fluka+Geant3 model
- I can also say, with some confidence, that a Flugg simulation will be more difficult to write.
- It was an excellent solution for MINOS which had:
  - An already well-understood Fluka-based target simulation
  - An already written Geant4 geometry